WHAT IS CLAIMED IS:

1. A method to design a feedback controller for extracting acoustic energy and structural energy in an acoustic enclosure comprising the steps of:

obtaining a continuous-time multi-input multi-output state-space mathematical model of the acoustic enclosure;

designing compensation to render the mathematical model passive in accordance with mathematical system theory if the mathematical model is not passive, thereby forming a compensated system that is passive;

checking passivity of the compensated system; and

designing a passivity-based controller such that a resulting closed-loop response provides a desired noise reduction.

2. The method of claim 1 further comprising the step of checking robustness of the compensated system.

3. The method of claim 1 wherein the step of obtaining a continuous-time multi-input multi-output state-space mathematical model of the acoustic enclosure comprises the step of obtaining a mathematical model having the form according to the equation

$$E\dot{x}(t) = Ax(t) + Bu(t) + Df(t)$$

4. The method of claim 1 wherein the step of designing a passivity-based controller includes designing a controller having a transfer function G(s) wherein

$$G(s) = Js^2 \sum_{k_1=0}^{l_1} \sum_{k_2=0}^{l_2} \sum_{k_3=0}^{l_3} \frac{\psi_{k_1k_2k_3}(x,y,z)}{s^2 + 2\zeta_{k_1k_2k_3}\omega_{k_1k_2k_3}s + \omega_{k_1k_2k_3}^2} [\sum_{n=1}^{P_1} \sum_{m=1}^{P_2} \frac{\alpha_{k_1k_2k_3nm}\phi_{nm}(x_{11},y_{11})}{s^2 + 2\zeta_{nm}\omega_{nm}s + \omega_{nm}^2}]$$

5. The method of claim 1 wherein the acoustic enclosure has a soft boundary and the step of designing a passivity-based controller includes designing a controller having a transfer function $G_{sb}(s)$ wherein

$$G_{sb}(s) = \sum_{i=1}^{l} \frac{\rho_0 s^2 c_0^2}{h\rho_p S_1} \cdot \frac{\Psi_i(r_0)}{s^2 + \rho_0 c_0^2 s D_{ii}(s) + c_0^2 \beta_{ii}} \cdot [\sum_{n=1}^{P_1} \sum_{m=1}^{P_2} \frac{\eta_{inm}\phi_{nm}(x_{11},y_{11})}{s^2 + 2\zeta_{nm}\omega_{nm}s + \omega_{nm}^2}]$$

6. The method of claim 1 wherein the step of designing compensation includes the step of designing a series passifier $C_s(s)$ according to $C_s(s) \sim \begin{cases} \dot{x}_c = A_c x_c + B_c u \\ u' = C_c x_c + D_c u \end{cases}$ wherein *Ac*, *Bc*, *Cc*, and *Dc* are determined according to the steps comprising:

solving the equation $\begin{bmatrix} A^{**} & (*) & (*) \\ \hat{A} + A^T & YA + A^T Y & (*) \\ \hat{D}^T B^T - CX - D\hat{C} & \hat{B}^T - C & D^{**} \end{bmatrix} < 0$ to obtain $X, Y, \hat{A}, \hat{B}, \hat{C},$ and $\hat{D}$;

constructing matrices *M*, *N*, and *P* such that

$P\Pi_1 = \Pi_2$ and $\Pi_1^T \Pi_2 = \begin{bmatrix} X & I \\ I & Y \end{bmatrix}$ where $XY + MN^T = I$, $\Pi_1 = \begin{bmatrix} X & I \\ M^T & 0 \end{bmatrix}$, $\Pi_2 = \begin{bmatrix} I & Y \\ 0 & N^T \end{bmatrix}$, $P = \begin{bmatrix} Y & N \\ N^T & * \end{bmatrix}$; and

solving the equations $\hat{A} = YAX + YBC_c M^T + NA_c M^T$, $\hat{B} = YBD_c + NB_c$, $\hat{C} = C_c M^T$, and $\hat{D} = D_c$ in reverse order to obtain *Ac*, *Bc*, *Cc*, and *Dc*.

7. The method of claim 1 wherein the step of designing compensation comprises the step of designing a feedforward compensator $C_{ff}(s)$ according to $C_{ff}(s) \sim \begin{cases} \dot{x}_c = A_c x_c + B_c u \\ y_2 = C_c x_c + D_c u \end{cases}$ wherein *Ac*, *Bc*, *Cc*, and *Dc* are determined according to the steps comprising:

solving the equation $\begin{bmatrix} AX + XA^T & (*) & (*) \\ \hat{A} + A^T & YA + A^T Y & (*) \\ B^T - CX - \hat{C} & B^T Y + \hat{B}^T - C & D^{\perp} \end{bmatrix} < 0$ where $D^{\perp} = -(D + D^T + \hat{D} + \hat{D}^T)$ to obtain $X, Y, \hat{A}, \hat{B}, \hat{C},$ and $\hat{D}$;

constructing matrices *M*, *N*, and *P* such that

$$P\Pi_1 = \Pi_2 \text{ and } \Pi_2^T \tilde{A} \Pi_1 = \begin{bmatrix} AX & A \\ YAX + NA_c M^T & YA \end{bmatrix} \text{ where } XY + MN^T = I,$$

$$\Pi_1 = \begin{bmatrix} X & I \\ M^T & 0 \end{bmatrix}, \Pi_2 = \begin{bmatrix} I & Y \\ 0 & N^T \end{bmatrix}, P = \begin{bmatrix} Y & N \\ N^T & * \end{bmatrix}; \text{ and}$$

solving the equations $\hat{A} = YAX + NA_c M^T$, $\hat{B} = NB_c$, $\hat{C} = C_c M^T$, and $\hat{D} = D_c$ in reverse order to obtain *Ac, Bc, Cc,* and *Dc*.

8. The method of claim 1 wherein the step of designing compensation comprises the step of performing sensor blending if there are redundant sensors.

9. The method of claim 1 wherein the step of designing compensation comprises the step of performing control allocation if there are redundant actuators.

10. The method of claim 1 wherein the step of designing compensation to render the mathematical model passive comprises the steps of:

determining if a feedforward compensation will passify the system;

if a feedforward compensation will not passify the system:

designing a constant gain feedforward compensation to render the compensated system minimum-phase; and

rendering the compensated system positive-real by at least one of series compensation, sensor-blending and control allocation.

11. The method of claim 10 wherein the step of designing a passivity-based controller comprises the step of designing one of a dissipative linear-quadratic-Gaussian (LQG) type positive-real controller and a dissipative constant gain positive-real controller.

12. The method of claim 10 wherein the step of rendering the compensated system positive-real by at least one of series compensation, sensor-blending and control allocation comprises the step of rendering the compensated system positive-real by at least one of series compensation, feedback compensation, hybrid compensation, and sensor-blending and control allocation.

13. The method of claim 1 further comprising the step of redesigning the compensation if the passivity is not preserved if mathematical model parameters are perturbed fro nominal values.

14. The method of claim 1 further comprising the step of performing numerical simulations of the controller in the presence of a simulated broadband disturbance input to determine if the closed-loop response is satisfactory.

15. The method of claim 14 further comprising the step of redesigning the controller if the close-loop response is not satisfactory.

16. The method of claim 1 wherein the step of designing compensation comprises the steps of:

designing a constant gain feedforward compensation to render the compensated system minimum-phase; and

rendering the compensated system positive-real by one of sensor-blending and control allocation.